School closures during COVID-19: an overview of systematic reviews

Samuel Hume[1] *, Samuel R. Brown[1], Kamal Ram Mahtani[2] *

1: Medical Sciences Division, University of Oxford, Oxford, UK

2: Nuffield Department of Primary Health Care Sciences, University of Oxford, Oxford, UK

* Corresponding authors: samuel.hume@st-annes.ox.ac.uk and kamal.mahtani@phc.ox.ac.uk

Abstract

Objectives

To assess the benefits and drawbacks of school closures and in-school mitigations during the COVID-19 pandemic.

Design

Overview of systematic reviews.

Search methods

We searched six databases and additional resources on 29 July 2022: MEDLINE, Embase, Google Scholar, Cochrane Library, COVID-END inventory of evidence synthesis, and Epistemonikos.

Eligibility criteria

We selected systematic reviews written in English that answered at least one of four specific questions concerning the efficacy and drawbacks of school closures. Their primary studies were conducted in primary and secondary schools, including pupils aged five to 18. Interventions included school closures, or mitigations (such as mask-usage) introduced in schools.

Data collection and analysis

We used AMSTAR 2 to assess confidence in the included systematic reviews, and GRADE was used to assess certainty of evidence. We performed a narrative synthesis of the results, prioritising higher quality SRs, those which performed GRADE assessments, and those with more unique primary studies. We also assessed the overlap between primary studies included in the systematic reviews.

Main outcome measures

Our framework for summarising outcome data was guided by the following questions: 1) What is the impact of school closures on COVID-19 transmission, morbidity, or mortality in the community? 2) What is the impact of COVID-19 school closures on mental health (e.g., anxiety), physical health (e.g., obesity, domestic violence, sleep), and learning/achievement of primary and secondary pupils? 3) What is the impact of mitigations in schools on COVID-19 transmission, morbidity, or mortality in the community? 4) What is the impact of COVID-19 mitigations in schools on mental health, physical health, and learning/achievement of primary and secondary pupils?

Results

We identified 578 reports, 26 of which were included. One systematic review was of high confidence, zero moderate, 10 low, and 15 critically low confidence. We identified 132 unique primary studies on the effects of school closures on transmission/morbidity/mortality, 123 on learning, 164 on mental health, 22 on physical health, 16 on sleep, seven on domestic violence, and 69 on effects of in-school mitigations on transmission/morbidity/mortality.

Both school closures and in-school mitigations were associated with reduced COVID-19 transmission, morbidity, and mortality in the community. School closures were also associated with reduced learning, increased anxiety, and increased obesity in pupils. We found no systematic reviews that assessed the drawbacks of in-school mitigations on pupils. The certainty of evidence according to GRADE was mostly very low.

Conclusions

School closures during COVID-19 had both positive and negative impacts. We found a large number of systematic reviews and primary studies. However, confidence in the systematic reviews was mostly low to very low, and the certainty of evidence was also mostly very low. We found no systematic reviews assessing the potential drawbacks of in-school mitigations on children, which could be addressed moving forward. This overview provides evidence that could inform policymakers on school closures during future potential waves of COVID-19.

Funding

No project-specific funding. KRM has received funding from NIHR SPCR Evidence Synthesis Working Group [project 390].

Registration

https://doi.org/10.6084/m9.figshare.19242774.v1

Summary box

What is already known?

COVID-19 has caused millions of global deaths since the end of 2019, and has seen unprecedented levels of public health intervention, including school closures, to reduce its transmission. However, the effectiveness of school closures in reducing transmission is still not fully understood. Similarly, potential negative effects on children have not been fully characterised.

What does this study add?

We performed an overview of systematic reviews to address these knowledge gaps. Evidence suggests a positive effect of school closures in reducing COVID-19 transmission, but also negative impacts. Children were reported to suffer reduced learning, increased anxiety, and increased obesity. Our study's limitations include that the specific impacts of school closures are difficult to separate from other non-pharmaceutical interventions introduced simultaneously, that we have reviewed a lack of data on Omicron variants, and that we were unable to perform meta-analysis.

How might this study affect policy?

This overview may inform pandemic planning policymakers when considering the benefits and harms of school closures during potential future waves of COVID-19.

Introduction

COVID-19 has caused worldwide morbidity and mortality, requiring pharmaceutical and non-pharmaceutical interventions (NPIs) to control its spread [1]. These NPIs include mask-wearing, social distancing, and school closures, all of which have been employed in most countries multiple times since the onset of the COVID-19 pandemic [2].

SARS-CoV-2, the virus that causes COVID-19, is highly transmissible and mutable, and has produced a number of variants of concern. Most recent is Omicron and its subvariants, which are more immune-evasive and more transmissible than previous strains [3,4]. These variants have caused worldwide records of COVID-19 infection, and induced further school closures [5]. The likely emergence of new variants in the future, causing new periods of exponential growth, means that school closures may continue to be considered by governments around the world.

The aim of school closures is to reduce social contacts, to cut transmission chains in the community [2]. However, their effectiveness remains uncertain, and whether the positive impacts of school closures on transmission outweigh potential negative impacts on children remains unknown. Despite most countries shutting schools during the COVID-19 pandemic, closures were generally not part of pandemic planning [6,7], and it is unclear whether the potential negative impacts were fully considered by policymakers.

The number of systematic reviews (SRs) on COVID-19 school closures, which have addressed this topic from multiple angles – with varying quality, and with conclusions that are not always consistent – provides an opportunity for an evidence synthesis from a wider perspective. Given this, we decided that an overview of SRs was the best study type.

Methods

The protocol for this overview was registered in February 2022 [8]. We conducted the overview in line with PRISMA guidelines (*https://prisma-statement.org/*), and with guidelines for reporting overviews [9–12].

Data sources

We searched MEDLINE via PubMed, Embase via Ovid, Google Scholar, the Cochrane Database of Systematic Reviews (CDSR), COVID-END inventory of evidence synthesis, and Epistemonikos, on 29 July 2022. References of included SRs were also hand-searched.

Search strategy

PubMed COVID-19 [tiab] AND (school* [tiab] OR college* [tiab]). Filter by article type: systematic review or meta-analysis.

Embase (COVID-19 AND (school* OR college*)).tw. Limit search to: systematic review or meta-analysis.

Google scholar allintitle: “COVID-19” “systematic review” school OR schools OR college OR colleges.

Cochrane library COVID-19 AND (school OR college). Limit search to Title Abstract Keyword, limit to Cochrane Reviews.

Epistemonikos Filter by COVID-19 evidence, school congregate setting, systematic review.

COVID-END Evidence about economic and social responses: Education section.

Inclusion and exclusion criteria

Only SRs (including rapid reviews) were included. Given the range of SRs published on this topic, whose results are not always consistent, we agreed that an overview of SRs was the best study design for a wide perspective on the topic. Only texts written in English were included, because we felt that we could not fairly review SRs written in other languages. Only SRs that answer at least one of the following four questions were included:

1) What is the impact of school closures (compared to no intervention) on COVID-19 transmission, morbidity, or mortality of people in the community?
2) What is the impact of school closures (compared to no intervention, or pre-COVID-19 levels) on mental health (e.g., anxiety), physical health (e.g., obesity, domestic violence, sleep), and learning/achievement of primary and secondary pupils (aged five-18)?
3) What is the impact of mitigations in schools (compared to no intervention) on COVID-19 transmission, morbidity, or mortality of people in the community?
4) What is the impact of mitigations in schools (compared to no intervention, or pre-COVID-19 levels) on mental health, physical health, and learning/achievement of primary and secondary pupils (aged five-18)?

Definition of terms

School closures: Shutting of education institutions for five-18 year olds, during the COVID-19 pandemic, resulting in students staying at home. *In-school mitigations*: Measures introduced to schools to reduce COVID-19 transmission, such as mask-wearing, social distancing, and isolation of positive COVID-19 cases. *Transmission*: spreading of SARS-CoV-2 from human to human, usually measured by PCR positivity, R-value, or secondary attack rate. *Morbidity*: COVID-19-induced hospitalisation. *Mortality*: COVID-19-induced death. *Impact*: Effect on transmission/morbidity/mortality, or on students; for example, on mental health (e.g., anxiety), physical health (e.g., obesity), or learning and achievement (e.g., test scores). *Systematic review*: A study that searches more than one database to answer a defined question, includes at least two primary studies answering that question, and identifies itself as a systematic review/meta-analysis/rapid review in the title. The study must be a full journal article (and not, for example, a conference abstract or protocol).

Study selection

Our search found 578 studies (452 initially, and 126 in the updated search), which were imported into Mendeley. 242 duplicates were removed, and screening was performed using the Rayyan software [13]. Articles were independently screened by two authors (SH and SRB), by title, abstract, and full text, according to our inclusion and exclusion criteria, and 26 SRs were ultimately included in the overview (Figure 1). Disagreements were resolved by discussion between all authors.

Data extraction

Two authors (SH and SRB) independently performed data extraction, according to a pre-defined data extraction table (Supplementary Table 1). Data extracted were first author/year, main questions asked in the study, study type, study period, search strategy, number of included studies, quality appraisal tool used, authors' assessment on quality of included studies, main conclusions, funding/conflicts of interest, journal, and which of our four posed questions the study addresses. Geographical areas covered in each SR, and the GRADE assessment performed by each SR, were later added.

Quality assessment

The AMSTAR 2 tool was used, which contains 16 criteria to assess the quality of SRs [14] (Table 1).

Critical domains in the AMSTAR 2 tool are as follows. Item 2) Has the protocol been pre-registered, and is the protocol comprehensive? Item 4) Is the literature search comprehensive? Item 7) Is a list of excluded studies provided, with exclusion reasons? Item 9) Is an appropriate risk of bias analysis performed? Item 11) Are the statistical analysis used in any meta-analysis appropriate? Item 13) Is the risk of bias considered when synthesising review results? Item 15) Is publication bias considered in studies that perform quantitative analysis?

SRs with zero or one non-critical weakness were rated as high quality, studies with multiple non-critical weaknesses as medium, SRs with one critical weakness as low, and SRs with multiple critical weaknesses as critically low [14].

Data synthesis

A narrative synthesis was performed. Each outcome was divided into independent sections in Results – for example, when assessing the impact of school closures on pupils, mental health was described in its own Results section. Within each Results section, SRs were described in order of quality (based on AMSTAR 2 assessments), with the highest quality SRs described first. SRs were then prioritised based on those that performed GRADE assessments (Supplementary Table 1), and subsequently based on those that contained a higher proportion of unique primary studies (Supplementary Table 3). Higher quality SRs were given more weight in concluding each outcome. Data were drawn from SR authors' conclusions and results, and additional details, such as quantification from meta-analysis, were also added if available. Our findings were summarised in Table 2.

GRADE assessments

For each outcome, GRADE assessments were used to assess the certainty of evidence [15,16]. GRADE ratings from included SRs were used if they were the only SR assessing that outcome, and if sufficient justification was given for the GRADE given. Otherwise, we performed GRADE assessments. All evidence was observational, and was therefore given a default GRADE of 'Low' certainty. GRADE certainties were downgraded if the evidence had high risk of bias, imprecision, inconsistency, or indirectness. Certainties were upgraded if there was a large magnitude of effect, or if there was a dose response gradient [15,16].

Deviation from protocol

Due to resource limitations, we excluded SRs not written in English in the final version of the review. We also included a fourth question in the final version of the overview not present in the protocol: what are the effects of COVID-19 mitigation strategies, implemented in schools, on transmission, morbidity, or mortality? This was an important question to add, to enable us to weigh the positive impacts of mitigations in schools (on transmission) against potential negative impacts (for example, on pupils' learning or mental health). In the manuscript, we added more detail to the review questions from the protocol. This increased the clarity of the review questions, and did not change their focus.

Patient and public involvement

Patients and the public were not involved in the planning or completion of the project.

Results

Results of search strategy

Figure 1 shows the PRISMA flow diagram for our overview. The search was performed on 20 February 2022, and was updated on 29 July 2022. 578 records were identified: 145 from PubMed, 217 from Embase, 80 from Google Scholar, 9 from Cochrane Library, 115 from Epistemonikos, and 12 from COVID-END. 242 of these records were excluded as duplicates. The remaining 336 records were screened, and 267 were excluded after reading titles or abstracts. The full texts of 69 articles were screened, and 43 were excluded (23 because they did not answer any of our four posed questions – see Methods section, 16 because they are not SRs, and four because they are not written in English – three are in Italian and one in German) (Figure 1). No further studies were added after searching included SRs' references, because none fit the inclusion criteria.

Authors	PICO clear	Protocol registered*	Included study designs explained	Comprehensive search strategy*	Duplicate screening	Duplicate data extraction	Excluded studies listed*	Full description of included studies	RoB assessed*	Funding of included studies stated	Appropriate statistics (in MA)*	RoB considered (in MA)	RoB considered in interpretation*	Explanation of heterogeneity	Publication bias considered (in MA)*	Conflict of interest declared	Rating
Zhang *et al.*, 2021	+	-	+	Partial +	+	+	-	+	+	-	+	+	+	+	+	+	**Critically Low**
NCCMT, 2021	+	-	+	Partial +	-	-	+	+	+	-	N/A	N/A	-	-	N/A	+	**Critically Low**
Walsh *et al.*, 2021	+	+	+	Partial +	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	**Low**
Kourti *et al.*, 2021	+	-	+	Partial +	+	+	-	+	+	-	N/A	N/A	-	+	N/A	+	**Critically Low**
Ayouni *et al.*, 2021	+	Partial +	+	Partial +	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	**Low**
Talic *et al.*, 2021	+	Partial +	+	Partial +	+	+	-	+	+	-	+	+	+	+	+	+	**Low**
Hammerstein *et al.*, 2021	+	-	+	Partial +	+	-	-	+	+	-	N/A	N/A	-	+	N/A	+	**Critically low**
Muhammed, 2020	+	-	+	Partial +	-	-	-	-	-	-	N/A	N/A	-	+	N/A	-	**Critically Low**
Bond *et al.*, 2021	+	-	+	Partial +	+	-	+	+	+	-	N/A	N/A	+	+	N/A	+	**Low**
Sharma *et al.*, 2021	+	Partial +	+	Partial +	+	+	-	+	+	-	+	+	-	+	+	+	**Critically Low**
Krishnaratne *et al.*, 2022	+	Partial +	+	Partial +	+	+	+	+	+	+	N/A	N/A	+	+	N/A	+	**High**
Elharake *et al.*, 2022	+	-	+	Partial +	+	+	-	+	-	-	N/A	N/A	-	-	N/A	+	**Critically Low**
Meherali *et al.*, 2021	+	Partial +	+	Partial +	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	**Low**
Nussbaumer-Streit *et al.*, 2020	+	Partial +	+	+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	**Low**
Samji *et al.*, 2021	+	Partial +	+	Partial +	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	**Low**
Viner *et al.*, 2020	+	-	+	Partial +	+	-	-	-	-	-	N/A	N/A	-	+	N/A	+	**Critically Low**

Viner *et al.*, 2022	+	Partial +	+	+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	**Low**
Lehmann *et al.*, 2022	+	-	+	Partial +	+	+	-	+	+	-	N/A	N/A	+	+	N/A	-	**Critically Low**
Panagouli *et al.*, 2021	+	-	+	Partial +	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	**Critically Low**
Mendez-Brito *et al.*, 2021	+	-	+	Partial +	+	-	-	+	+	-	N/A	N/A	+	+	N/A	+	**Critically Low**
Chaabane *et al.*, 2021	+	Partial +	+	Partial +	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	**Low**
Chai *et al.*, 2021	+	+	-	Partial +	-	-	-	+	+	-	+	+	+	+	+	+	**Low**
Suk *et al.*, 2020	+	-	+	Partial +	+	+	-	+	-	-	N/A	N/A	-	+	N/A	-	**Critically Low**
Vardavas *et al.*, 2021	+	-	+	Partial +	+	+	-	+	-	-	N/A	N/A	-	+	N/A	+	**Critically Low**
Chang *et al.*, 2021	+	-	-	Partial +	+	+	-	+	+	-	+	+	+	+	+	+	**Critically Low**
Caini *et al.*, 2022	+	-	+	Partial +	-	+	-	+	+	-	+	+	+	+	+	+	**Critically Low**

Table 1: AMSTAR 2 quality appraisal. Stars indicate critical domains. MA: meta-analysis. RoB: Risk of Bias. SRs with zero or one non-critical flaw score 'High', studies with multiple non-critical flaws score 'Medium', studies with one critical flaw score 'Low', and studies with multiple critical flaws score 'Critically low'. SRs are awarded a Partial + in 'Protocol registered' if they register a protocol, but the protocol is not comprehensive, and a Partial + in 'Comprehensive search strategy' if, for example, authors search at least two databases, but no not scan included articles' bibliographies. Full details of the AMSTAR 2 appraisal tool are available at Shea *et al.*, BMJ 2017 [14].

This gave rise to 26 SRs to include in the review: 11 SRs assessing the impact of COVID-19 school closures on transmission, morbidity or mortality, 14 SRs assessing the impact of COVID-19 school closures on children, three SRs assessing the impact of COVID-19 in-school mitigations on transmission, morbidity or mortality, and zero SRs assessing the impact of COVID-19 in-school mitigations on children. Supplementary Table 1 lists the main characteristics of the included studies. Supplementary Table 2 lists the 310 reports identified by our search strategy but excluded from the synthesis.

Quality assessment of included SRs

We used the AMSTAR 2 quality appraisal method [14] to assess confidence in the included SRs. We assessed one of the included SRs to be high confidence, zero medium, 10 low, and 15 critically low confidence (Table 1). SR quality was downgraded for a number of reasons. Fifteen SRs did not register a protocol, four did not perform screening in duplicate, seven did not perform data extraction in duplicate, 23 did not list excluded studies, two did not include a full description of included studies, five did not assess risk of bias, 25 did not list the funding sources of included primary studies, nine did not consider risk of bias in interpretation, two did not explain heterogeneity, and three did not declare conflicts of interest (Table 1).

Overlap

The relevant primary studies included in each SR, and their overlap, are shown in Supplementary Table 3. The average number of unique primary studies in each group of SRs was as follows: 66% (range: 25-100%, n=11 SRs) for school closures and COVID-19 transmission/ morbidity/ mortality, 89% (range: 69-100%, n=4 SRs) for school closures and learning, 48% (range: 0-89%, n=8 SRs) for school closures and mental health, 85% (range: 67-100%, n=3 SRs) for school closures and physical health. 42% (range: 0-67%, n=3 SRs) for school closures and sleep, 74% (range: 67-80%, n=2 SRs) for school closures and domestic violence, and 100% (range: 100-100%, n=3 SRs) for in-school mitigations and COVID-19 transmission/ morbidity/ mortality (Supplementary Table 3). SRs with a higher proportion of unique primary studies were prioritised when synthesising results.

What is the impact of school closures on COVID-19 transmission, morbidity, or mortality of people in the community?

Eleven SRs addressed the impact of school closures on COVID-19 transmission, morbidity, or mortality [17–27]. Six SRs reported a reduction in transmission upon school closures [20–23,25,27], two SRs reported an uncertain effect on transmission of school closures [18,19], and two SRs reported no effect on transmission of school re-openings [17,18]. One SR reported a reduction in hospitalisations upon school closures [26], and one reported a reduction in mortality upon school closures [24]. One SR reported the GRADE certainty for reduced transmission upon school closures to be low [23], one for no effect on transmission of re-opening schools to be low [17], and one for reduced hospitalisation upon school closures to be low [26] (Table 2).

Low quality SRs

Chaabane *et al*. (Unique primary studies: 100%) reported that school closures may have reduced paediatric hospitalisations [26]. The Nussbaumer-Streit *et al*. SR (Unique studies: 67%) reported that adding school closures onto other measures, such as mandatory quarantine for infected students, may have reduced transmission over quarantine alone [23]. Walsh *et al.* (Unique: 64%) reported uncertain findings on school closures: half of the included primary studies at lower risk of bias found reduced community COVID-19 transmission upon closing schools, while the other half reported that school closures were associated with no change in transmission. This SR further reported that school re-opening was mostly not associated with increased community transmission, when community transmission was low and in-school mitigations were in place [18].

Talic *et al*. (Unique: 60%) reported that school closures were largely effective. Primary studies included in this SR were inconsistent on the efficacy of school closures, although most supported reduced community COVID-19 transmission upon school closure [21]. The Ayouni *et al*. SR (Unique: 50%)

reported that school closures were associated with reduced community transmission, but also that the specific effects of school closures were difficult to disaggregate, given the other NPIs introduced at the same time [20].

Critically low quality SRs

The National Collaborating Centre for Methods and Tools (NCCMT) (Unique: 82%) reported little evidence that re-opening schools increased transmission when mitigations, such as mask-usage, were in place [17]. Caini *et al*. (Unique: 87%) found that children may be less likely to transmit COVID-19 than adults, leading to limited transmission in schools [19]. In meta-analyses of observational studies, Caini *et al*. reported that onward transmission from school pupils was less likely than from adults (OR 0.26, 95% CI [0.11-0.63]) and school pupils were also less likely to be infected with COVID-19 (OR: 0.60, 95% CI [0.25-1.47]) [19].

Viner *et al*. (2020) (Unique studies: 67%) is an SR from very early in the pandemic (the latest search was 19 March 2020), but predicted - from primary modelling studies - a very small beneficial effect of school closures on community COVID-19 mortality [24]. The Muhammed SR reported that school closures may have been effective in reducing COVID-19 transmission (Unique studies: 63%). Effectiveness appeared to be dependent on infection levels in the community, and the time that closures were introduced: earlier interventions, when community levels remained relatively low, were reported to be more effective [22].

The Mendez-Brito *et al*. SR (Unique: 60%) concluded that school closures may be the most effective NPI, and were more effective when introduced earlier: 58% of included primary studies reported reduced transmission upon school closure [25]. Finally, Suk *et al*. included few unique studies (Unique: 25%), but reported that school children were rarely the index case for subsequent household transmission. Nevertheless, this SR reported that school closures may have reduced COVID-19 transmission [27].

Taken together, the evidence suggests that school closures may have reduced community COVID-19 transmission, morbidity, and mortality. A limitation of these data is that only one of the SRs performed quantitative meta-analysis. In most of the SRs, most of the included primary studies were unique (Supplementary Table 3). The quality of the evidence was variable, with all studies of low or critically low quality (Table 1), although exclusion of the SRs with critically low quality does not change the overall conclusion. The GRADE certainty for the evidence in transmission, morbidity, and mortality is all very low (Table 2).

What is the impact of school closures on pupils' learning and achievement?

Four SRs assessed the impact of school closures on pupils' learning and achievement [26,28–30]. Four SRs reported a decline in learning and achievement associated with school closures [26,28–30]. One SR assessed the certainty of the evidence by GRADE, which was reported as low [26] (Table 2).

Low quality SRs

Chaabane *et al.* (Unique: 100%) reported that students from lower socio-economic backgrounds, and those with disabilities, may have fared worse with online learning, due to reduced access to the internet and technology at home [26]. Bond *et al*.'s SR (Unique: 96%) reported that some students were less engaged, and attendance was reduced, for virtual teaching at home – potentially due to social isolation. Furthermore, it appeared that some pupils lacked the technical skills required for the virtual learning to be effective [30].

Critically low quality SRs

Hammerstein *et al*. (Unique: 91%) found loss of learning upon closing schools, particularly affecting younger pupils and pupils from low socioeconomic backgrounds. The estimated learning loss was in the range of -0.005 - -0.05 *SD* per week of closures [28]. Similarly, Panagouli *et al*. (Unique: 69%) reported that loss of learning upon school closures was more severe in younger pupils and pupils with special educational needs (SEN). However, the SR also reported evidence that some students appeared to gain more from virtual learning than classical classroom teaching [29].

Together, these SRs suggest that learning loss occurred during school closures, and SEN students, as well as those from lower socioeconomic backgrounds, appeared to be most affected. It appears that some students engaged less with virtual teaching methods than in-person methods, and virtual teaching may have exacerbated inequalities. There was minimal overlap between primary studies included in the SRs (Supplementary Table 3), but the studies were of low or critically low quality (Table 1), and the GRADE certainty for this evidence base is low (Table 2).

What is the impact of school closures on pupils' mental health?

Eight SRs assessed the impact of school closures on pupils' mental health [26,31–37]. Eight SRs reported a decline in mental health associated with school closures [26,31–37]. One SR assessed the certainty of evidence using GRADE, which reported the evidence as low certainty [26] (Table 2).

Low quality SRs

Chaabane *et al*. (Unique: 25%) reported increased anxiety and loneliness among students during school closures [26]. Samji *et al*. (Unique studies: 89%) reported that female students were worse affected, as well as older students and pupils with neurodiversity. Nevertheless, effects on mental health could be mitigated, including if students exercised more at home or had better social support networks [34].

Viner *et al*. (2022) (Unique: 60%) reported increased anxiety and reduced wellbeing during school closures, but no change in suicide rate [35]. Chai *et al*. performed a meta-analysis of cross-sectional studies (Unique: 42%), reporting that 28% (95% CI [22-34%]) of Chinese students experienced mental health problems during school closures for COVID-19 – compared to best estimates (in a different population) of 17.6% (95% CI [17.4-17.9%]) before the pandemic [37,38]. Meherali *et al*. (Unique: 23%) reported worse effects on mental health among female students, as well as among those who spent more time on social media – usage of which also appeared to increase during school closures [33].

Critically low quality SRs

Lehmann *et al*. (Unique: 80%) reported worsening behaviour and hyperactivity among students, and noted that students' mental health during school closures became worse if their parents were suffering from stress. Lehmann *et al*. caveat that unequivocal conclusions were difficult to draw, since multiple NPIs were often introduced simultaneously [36].

Zhang *et al*.'s meta-analysis of cross-sectional studies (Unique: 64%) reported that the prevalence of anxiety among Chinese students during the COVID-19 pandemic was 24% (95% CI [20-29%]). In subgroup analyses, Zhang *et al*. reported that anxiety appeared to be worse in the diffusion attenuation phase of the pandemic (42%, 95% CI [35-50%]) than in the outbreak phase (25%, 95% CI [17-34%]) [31]. Although they did not include any primary studies unique from the above SRs, Elharake *et al*. (Unique: 0%) also reported a decline in mental health during school closures, and reported that risk factors for this included low socioeconomic status, and having family members who work in healthcare [32].

Overall, these SRs suggest that COVID-19 school closures may have increased the prevalence of mental health problems – most notably anxiety – among children. A limitation of these data is that school closures were not applied as a solitary restriction; some effects on mental health may therefore also be effects of other restrictions, or from the wider context of the COVID-19 pandemic. There was moderate overlap between primary studies, and one SR (Elharake *et al*.) presented zero unique primary studies (Supplementary Table 3). The studies were of low or critically low quality (Table 1), and the GRADE certainty for this evidence base is very low (Table 2).

What is the impact of school closures on pupils' physical health?

Three SRs assessed the impact of school closures on pupils' physical health [26,35,39]. Three SRs reported a decline in physical health associated with school closures [26,35,39]. One SR assessed the certainty of evidence using GRADE, which reported low certainty in the evidence [26] (Table 2).

Low quality SRs

Chaabane *et al*. (Unique: 67%), reported that school closures were associated with an increase in BMI and obesity, with predictions showing that longer closures would be associated with larger increases [26]. Similarly, Viner *et al*. (2022) (Unique: 88%) reported that school closures were associated with weight gain in children, as well as with reduced exercise, increased sedentary behaviour, and increased unhealthy food consumption [35].

Critically low quality SRs

Chang *et al*.'s meta-analysis of non-randomised studies (Unique: 100%) reported that the average BMI of pupils increased by 0.77 points (95% CI [0.33-1.20] p=0.0006), rates of obesity increased by 1.23-fold (95% CI [1.10-1.37] p=0.0002), and the average increase in bodyweight was 2.67 kg (95% CI [2.12-3.23] p<0.00001) (noted by the authors to be a greater increase than normal average growth), following COVID-19 lockdowns [39].

Overall, these SRs suggest that school closures may have increased BMI and obesity among pupils – potentially due to reduced exercise coupled with a less healthy diet at home, where students did not have access to physical education teaching or healthy school meals. Given that school closures were not applied on their own, these changes may also reflect the wider context of the pandemic. There was little overlap between primary studies (Supplementary Table 3), but the SRs were of low or critically low quality (Table 1), and the GRADE certainty for this evidence base is very low (Table 2).

What is the impact of school closures on pupils' sleep?

Three SRs assessed the impact of school closures on pupils' sleep [26,35,40]. Two SRs reported a decline in sleep quality associated with school closures [35,40], and one SR reported no change to sleep quality associated with school closures [26] (Table 2).

Low quality SRs

Most of the 10 primary sleep studies included in the Viner *et al*. (2022) SR (Unique: 60%) reported reduced sleep quality during school closures, with many students developing new sleep problems and fewer students sleeping through the night [35]. Although they only included one primary study on sleep, which was not unique, Chaabane *et al*. (Unique: 0%) concluded that sleep timing (but not sleep quality) was affected during school closures [26].

Critically low quality SRs

Sharma *et al*. (Unique: 67%) conducted a synthesis of nine primary studies and reported that, in general, students slept later and woke later during school closures. They also reported that some students had better sleep quality during school closures, but three-times this number experienced a decline in sleep quality [40]. Meta-analysis found that 54% of pupils (95% CI [50-57%]) had sleep disturbance, and 49% (95% CI [39-58%]) did not achieve recommended sleep quantities during the pandemic [40].

Although the quality of the SRs and their findings varied, there appears to be a trend to suggest that sleep quality reduced during school closures. This may be due to a mixture of increased anxiety and reduced physical activity. Nevertheless, there was some evidence that a subgroup of students reverted to a more natural sleeping routine, with many sleeping later and waking later. These changes could reflect school closures directly, but cannot be separated from the potential wider context of the COVID-19 pandemic. There was moderate overlap between primary studies, and one SR (Chaabane *et al*.) presented zero unique primary studies (Supplementary Table 3). The SRs were of low or critically low quality (Table 1), and the GRADE certainty for this evidence base is very low (Table 2).

What is the impact of school closures on domestic violence against children?

Two SRs assessed the impact of school closures on domestic violence against children [35,41]. One SR reported an increase in domestic violence associated with school closures [41], and one SR reported an uncertain effect of school closures on domestic violence [35] (Table 2).

Low quality SRs

Viner *et al*. (2022) (Unique: 67%) described a consistent reduction in reports of child abuse during school closures, although no findings on incidence of abuse [35].

Critically low SRs

Kourti *et al*. (Unique: 80%) described that, around the world, reported cases of domestic violence against children reduced during school closures. Despite this, some studies suggested increased incidence of abuse, including increased numbers of children presenting to healthcare centres with abusive head trauma. Kourti *et al*. suggested that this may be due to co-quarantine of perpetrators and victims [41].

Together, these SRs suggest that *reported* cases of domestic violence may have reduced during school closures, but *actual* cases may have increased. There was little overlap between the primary studies in the SRs (Supplementary Table 3). However, the studies were of low or critically low quality (Table 1), and the GRADE certainty for the evidence base is very low (Table 2).

What is the impact of in-school mitigations on COVID-19, transmission, morbidity, and mortality?

Three SRs addressed the effects of in-school mitigations on COVID-19 transmission, morbidity, or mortality [17,42,43]. Three SRs reported that in-school mitigations were associated with reduced transmission [17,42,43], one SR reported an association with reduced hospitalisations [42], and one SR reported an association with reduced mortality [42] (Table 2). One SR reported the GRADE certainty for reduction in transmission as low [17], and the another reported the GRADE certainty for the reduction in transmission, morbidity, and mortality as very low [42].

High quality SRs

Krishnaratne *et al*. (Unique: 100%) reported that in-school mitigations, such as mask-wearing and isolation of positive cases, appeared to be effective in reducing community COVID-19 transmission, hospitalisation, and mortality [42].

Critically low quality SRs

The NCCMT (Unique: 100%) found that mask-usage, social distancing, restricting school entrance to non-staff/non-students, stopping extracurricular activities, teaching outdoors, and screening for symptoms of COVID-19, all appeared to reduce transmission in schools [17]. Vardavas *et al*. (Unique: 100%) also reported that the mitigations introduced in schools appeared effective in reducing transmission, with little transmission occurring in schools when these measures were in place [43].

Overall, these SRs suggest that the mitigations implemented in schools, such as mask-usage, may be effective in reducing school and community transmission of COVID-19. There was no overlap between the primary studies included in the SRs (Supplementary Table 3). One SR was high quality, but the others were of critically low quality (Table 1); the conclusions of the high quality study (Krishnaratne *et al*.) were consistent with those of the other studies. The GRADE certainties for this evidence base - for the effect of in-school mitigations on transmission, morbidity, and mortality - are all very low (Table 2).

What is the impact of in-school mitigations during COVID-19 on children?

We found no SRs that addressed our fourth question: the effect of in-school mitigations on children (for example, on learning, physical or mental health).

Question	Unique primary studies	Outcome	Result	Magnitude of effect	GRADE
1: What is the effect of school closures on community COVID-19 transmission, morbidity, and mortality?	132	Transmission	Reduced: 6 SRs [20–23,25,27] (closures) Uncertain: 2 SRs [18,19] (closures) No effect: 2 SRs [17,18] (re-openings)	• Transmission from pupils less likely than from adults (OR 0.26, 95% CI [0.11-0.63] [19] (Meta-analysis) • Pupils less likely to be infected than adults (OR 0.6, 95% CI [0.25-1.47] [19] (Meta-analysis)	Very low[1] ⊕◯◯◯
		Hospitalisation	Reduced: 1 SR [26]	• 45% reduction in paediatric hospital admissions [26]	Very low[2] ⊕◯◯◯
		Mortality	Reduced: 1 SR [24]	• 2-4% reduction in deaths [24]	Very low[3] ⊕◯◯◯
2: What is the effect of school closures on children's health?	123	Learning	Worse: 4 SRs [26,28–30]	• Learning loss of -0.005 - -0.05 *SD*, per week of closures [28]	Low ⊕⊕◯◯
	164	Mental health	Worse: 8 SRs [26,31–37]	• Prevalence of anxiety during COVID-19: 24% (95% CI [20-29%]) [31] (Meta-analysis) • Anxiety in outbreak phase: 25% (95% CI [17-34%]) [31] (Meta-analysis) • Anxiety in diffusion attenuation phase: 42% (95% CI [35-50%]) [31] (Meta-analysis) • Prevalence of mental health problems during COVID-19: 28% (95% CI [22-34%]) [37] (Meta-analysis)	Very low[4] ⊕◯◯◯
	22	Physical health	Worse: 3 SRs [26,35,39]	• BMI increased by 0.77 units (95% CI [0.33-1.2]) p=0.0006), obesity prevalence by 1.23-fold (95% CI [1.1-1.37]) p=0.0002), and bodyweight by 2.67 kg (95% CI [2.12-3.23]) p<0.00001 [39] (Meta-analysis)	Very low[5] ⊕◯◯◯
	16	Sleep	Worse: 2 SRs [35,40] No effect: 1 SR [26]	• 54% (95% CI [50-57%]) had sleep disturbance [40] (Meta-analysis) • 49% (95% CI [39-58%]) did not achieve recommended sleep quantities [40] (Meta-analysis)	Very low[6] ⊕◯◯◯
	7	Domestic violence	Increased: 1 SR [41] Uncertain: 1 SR [35]	• 67% reduction in reported cases of domestic violence involving children [41] • 41% reduction in police reports for domestic violence involving children [41] • Estimated Increase in victims of violence against children: 11,488,186-18,381,098 in Africa, 3,577,839-5,724,542 in Asia, 2,921,466-4,674,345 in Latin America, 759,600-1,215,360 in Europe, 2,009,722-3,215,554 in North America, and 32,010 – 51,216 in Oceania [41]	Very low[7] ⊕◯◯◯
3: What is the effect of in-school mitigations on community COVID-19 transmission, morbidity, or mortality?	69	Transmission	Reduced: 3 SRs [17,42,43]	• Mask usage in schools associated with reduction in R in community by 0.011 (95% CI [0.008-0.0127]) [42]	Very low[8] ⊕◯◯◯
		Hospitilisation	Reduced: 1 SR [42]	• Mask usage in schools associated with reduction in excess hospitalisation per 10,000 of population in teachers to 4.2 (95% CI [-47.39-48.09]) from 40.5 (95% CI [-46.95-146.64]), and in students to 0.07 (95% CI [0.00 – 0.01]) from 0.08 (95% CI [0.00-0.08]) [42]	Very low[9] ⊕◯◯◯
		Mortality	Reduced: 1 SR [42]	• Mask usage in schools associated with reduction in community mortality by ratio of 1.5 (95% CI [1.5-1.6]) [42]	Very low[10] ⊕◯◯◯
4: What is the effect of in-school mitigations on children's health?	0	Children's health	0 SRs	Not available	-

[1] Downgraded for risk of bias and inconsistency; [2] Downgraded for imprecision. [3] Downgraded for imprecision and risk of bias. [4] Downgraded for risk of bias. [5] Downgraded for risk of bias. [6] Downgraded for inconsistency and imprecision. [7] Downgraded for indirectness. [8] Downgraded for indirectness and imprecision. [9] Downgraded for risk of bias, indirectness and imprecision. [10] Downgraded for risk of bias, indirectness and imprecision.

Number of unique studies in individual SRs. For question 1 - [20]: 2, [21]: 3, [22]: 5, [23]: 4, [25]: 15, [27]: 3, [26]: 1, [24]: 4, [17]: 14, [18]: 25, [19]: 34. For question 2 (learning) – [28]: 1, [30]: 77, [29]: 29, [26]: 3. For question 2 (mental health) - [31]: 7, [32]: 0, [33]: 3, [34]: 103, [35]: 15, [36]: 8, [26]: 1, [37]: 5. For question 2 (physical health) - [35]: 7, [26]: 2, [39]: 12. For question 2 (sleep) - [40]: 6, [35]: 6, [26]: 0. For question 2 (domestic violence) - [41]: 4, [35]: 2. For question 3 - [17]: 17, [42]: 38, [43]: 14.

Table 2: Summary of findings. Data from meta-analysis were prioritised to represent effect measures for each outcome, where available.

Discussion

We performed an overview of 26 SRs to assess the positive and negative impacts of school closures, and in-school mitigations, during COVID-19. We found evidence that both school closures and in-school mitigations may have had a beneficial impact on reducing COVID-19 transmission in the community. However, the GRADE certainty was very low in both outcomes. We also found that school closures may have had negative impacts on children, including reduced learning, increased anxiety, and increased rates of obesity. However, GRADE certainties were low or very low in these outcomes (Table 2). Overall, confidence in the included SRs was generally low or critically low (Table 1).

We observed some heterogeneity across the evidence base, particularly related to the impact of school closures on community transmission. A likely source of heterogeneity is that studies were performed in different countries, at different times of the pandemic, with different SARS-CoV-2 variants and different vaccination coverage (Supplementary Table 1). Exclusion of the SRs with critically low quality does not change our overall conclusion that school closures were associated with reduced community COVID-19 transmission, suggesting that SR quality does not account for the heterogeneity.

There have not been any randomised controlled trials that have assessed the impact of school closures on COVID-19 transmission, which also likely contributes to the heterogeneity. For this reason, it is difficult to disaggregate the specific effect of each intervention, when multiple NPIs were introduced simultaneously. This also contributes to the low and very low GRADE certainties across individual outcomes, and means that recommendations to policymakers should be made with caution. Similarly, the quality of included SRs, measured by the AMSTAR 2 tool [14], is generally low or critically low, highlighting the need for high-quality SRs in the future.

A recent study looked to address the lack of randomised studies using a retrospective approach, by matching the closed and open schools that were most similar in terms of potential confounding factors. This study, based in Japan, found that school closures were not associated with reduced community transmission of COVID-19 [44].

A main reason to close schools is to protect the family of school children from household COVID-19 transmission. However, none of the included SRs accounted for household size or number of vulnerable family members when assessing the efficacy of school closures on morbidity and mortality in the community. This is a limitation of our study, and should be addressed moving forward.

Another limitation of our study is that none of the SRs we have reviewed feature the currently-dominant Omicron subvariants. This could reduce the applicability of our study's findings with respect to the ongoing evolution of the pandemic, although it should be noted that the recent Omicron waves caused fewer deaths than previous waves [45]. Similarly, the original COVID-19 vaccines have retained their protection against severe disease from Omicron [46], and vaccination considerably reduced COVID-19 fatality rates during Omicron waves [47]. Moving forward, this protection is increased further by a bivalent booster dose containing Omicron's Spike mRNA, which is now being used in booster programs across the world [48]. Despite increased transmission of Omicron *vs*. previous variants, including in schools [49], the continued vaccination of children [50], which was not widespread in previous waves, may compensate for the transmission advantage of Omicron.

Although we have reviewed a lack of Omicron data, a recent study, which looked at the efficacy of mask usage in schools during Omicron waves, found evidence consistent with our conclusions. This study assessed the effects of removing school mask rules in the US during February – June 2022, when Omicron variants were dominant [51]. The study found that removal of mask rules in schools was associated with 44.9 extra COVID-19 cases per thousand students and staff (95% CI [32.6-57.1]), representing 29.4% of all COVID-19 cases during the study period, and highlighting the efficacy of masks in schools, including against Omicron [51].

Although we were able to analyse most of our planned outcomes, we found no SRs that assessed the effect of in-school mitigations – like masks and social distancing – on children's health and well-being. Given the importance of considering an intervention's negatives alongside its positives, this is an area that should receive additional research attention in the future.

A final limitation is that we were unable to perform quantitative meta-analysis due to a lack of amenable data, so we were limited to narrative synthesis.

In conclusion, our findings suggest that the benefits of school closures in reducing community transmission of COVID-19 should be considered in the context of the harms on children's education, health, and wellbeing. This overview may inform future planning for school closures during pandemic outbreaks.

Figure legends

Figure 1: PRISMA flow diagram. A full list of excluded studies is provided in Supplementary Table 2.

Supplementary Table 1: Characteristics of included SRs. We have only listed the questions and study conclusions that are relevant for our study.

Supplementary Table 2: List of excluded studies. Studies excluded as duplicates are not shown.

Supplementary Table 3: Assessment of primary study overlap in the included SRs. Duplicate studies are highlighted. The first three authors of each primary study are shown. Available from https://doi.org/10.6084/m9.figshare.21803883.v1 [52].

Funding No project-specific funding. KRM has received funding from the NIHR SPCR Evidence Synthesis Working Group [project 390].

Author contributions KRM had the idea for the review as a project led by SH. SH performed searches. SH and SRB screened articles for inclusion. SH and SRB extracted data. SH wrote the article and prepared figures and tables, with comments from KRM. All authors approved the final manuscript.

Acknowledgements The authors are grateful to Nia Roberts (University of Oxford), for advising on the search strategy. The host institutions and any associated sponsors had no role in study design, data collection, analysis, decision to publish or preparation of the manuscript. The views presented in this report are those of the authors solely.

Competing interests The authors declare no competing interests.

References

1 COVID-19 Excess Mortality Collaborators. Estimating excess mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19-related mortality, 2020-21. *Lancet (London, England)* Published Online First: March 2022. doi:10.1016/S0140-6736(21)02796-3

2 Mahtani KR, Heneghan C, Aronson JK. What is the evidence for social distancing during global pandemics? A rapid summary of current knowledge. *Cent Evidence-Based Med* 2020;:1–9.https://www.cebm.net/covid-19/what-is-the-evidence-for-social-distancing-during-global-pandemics/

3 Iketani S, Liu L, Guo Y, *et al.* Antibody evasion properties of SARS-CoV-2 Omicron sublineages. *Nature* Published Online First: March 2022. doi:10.1038/s41586-022-04594-4

4 Hachmann NP, Miller J, Collier A-RY, *et al.* Neutralization Escape by SARS-CoV-2 Omicron Subvariants BA.2.12.1, BA.4, and BA.5. N. Engl. J. Med. 2022;**387**:86–8. doi:10.1056/NEJMc2206576

5 Colosi E, Bassignana G, Barrat A, *et al.* Minimizing school disruption under high incidence conditions due to the Omicron variant in early 2022. *medRxiv* 2022;:2022.02.04.22270473. doi:10.1101/2022.02.04.22270473

6 Timmins N. Schools and coronavirus: The government's handling of education during the pandemic. Institute for Government. 2021.

7 NAO. The government's preparedness for the COVID-19 pandemic: lessons for government on risk management. National Audit Office. 2021.

8 Hume S, Mahtani KR. Impact of school closures and mitigation strategies during the COVID-19 pandemic [protocol]. Published Online First: 2022. doi:https://doi.org/10.6084/m9.figshare.19242774.v1

9 Bougioukas KI, Bouras E, Apostolidou-Kiouti F, *et al.* Reporting guidelines on how to write a complete and transparent abstract for overviews of systematic reviews of health care interventions. *J Clin Epidemiol* 2019;**106**:70–9. doi:10.1016/j.jclinepi.2018.10.005

10 Gates M, Gates A, Pieper D, *et al.* Reporting guideline for overviews of reviews of healthcare interventions: development of the PRIOR statement. *BMJ* 2022;**378**:e070849. doi:10.1136/bmj-2022-070849

11 Santesso N, Glenton C, Dahm P, *et al.* GRADE guidelines 26: informative statements to communicate the findings of systematic reviews of interventions. *J Clin Epidemiol* 2020;**119**:126–35. doi:10.1016/j.jclinepi.2019.10.014

12 Campbell M, McKenzie JE, Sowden A, *et al.* Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. *BMJ* 2020;**368**:l6890. doi:10.1136/bmj.l6890

13 Ouzzani M, Hammady H, Fedorowicz Z, *et al.* Rayyan-a web and mobile app for systematic reviews. *Syst Rev* 2016;**5**:210. doi:10.1186/s13643-016-0384-4

14 Shea BJ, Reeves BC, Wells G, *et al.* AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ* 2017;**358**:j4008. doi:10.1136/bmj.j4008

15 Meader N, King K, Llewellyn A, *et al.* A checklist designed to aid consistency and

reproducibility of GRADE assessments: development and pilot validation. *Syst Rev* 2014;**3**:82. doi:10.1186/2046-4053-3-82

16 Guyatt GH, Oxman AD, Vist GE, *et al.* GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008;**336**:924–6. doi:10.1136/bmj.39489.470347.AD

17 National Collaborating Centre for Methods and Tools. Living Rapid Review update 17: What is the specific role of daycares and schools in COVID-19 transmission? *Ecdc* 2021;**(August),**.

18 Walsh S, Chowdhury A, Braithwaite V, *et al.* Do school closures and school reopenings affect community transmission of COVID-19? A systematic review of observational studies. *BMJ Open* 2021;**11**:e053371. doi:10.1136/bmjopen-2021-053371

19 Caini S, Martinoli C, C LV, *et al.* SARS-CoV-2 Circulation in the School Setting: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health* 2022;**19**. doi:10.3390/ijerph19095384

20 Ayouni I, Maatoug J, Dhouib W, *et al.* Effective public health measures to mitigate the spread of COVID-19: a systematic review. *BMC Public Health* 2021;**21**:1015. doi:10.1186/s12889-021-11111-1

21 Talic S, Shah S, Wild H, *et al.* Effectiveness of public health measures in reducing the incidence of covid-19, SARS-CoV-2 transmission, and covid-19 mortality: systematic review and meta-analysis. *BMJ* 2021;**375**:e068302. doi:10.1136/bmj-2021-068302

22 Muhammed ZF. Effects of school closure on transmission of COVID-19. A rapid systematic review. *Kurdistan J Appl Res* 2020;**5**:106–11.

23 Nussbaumer-Streit B, Mayr V, Dobrescu AI, *et al.* Quarantine alone or in combination with other public health measures to control COVID-19: a rapid review. *Cochrane database Syst Rev* 2020;**4**:CD013574. doi:10.1002/14651858.CD013574

24 Viner RM, Russell SJ, Croker H, *et al.* School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review. *Lancet Child Adolesc Heal* 2020;**4**:397–404. doi:10.1016/S2352-4642(20)30095-X

25 Mendez-Brito A, El Bcheraoui C, Pozo-Martin F. Systematic review of empirical studies comparing the effectiveness of non-pharmaceutical interventions against COVID-19. *J Infect* 2021;**83**:281–93. doi:10.1016/j.jinf.2021.06.018

26 Chaabane S, Doraiswamy S, Chaabna K, *et al.* The Impact of COVID-19 School Closure on Child and Adolescent Health: A Rapid Systematic Review. *Child (Basel, Switzerland)* 2021;**8**. doi:10.3390/children8050415

27 Suk JE, Vardavas C, Nikitara K, *et al.* The role of children in the transmission chain of SARS-CoV-2: a systematic review and update of current evidence. *medRxiv* Published Online First: 2020. doi:10.1101/2020.11.06.20227264

28 Hammerstein S, König C, Dreisörner T, *et al.* Effects of COVID-19-Related School Closures on Student Achievement-A Systematic Review. Front. Psychol. 2021;**12**:746289. doi:10.3389/fpsyg.2021.746289

29 Panagouli E, Stavridou A, Savvidi C, *et al.* School Performance among Children and Adolescents during COVID-19 Pandemic: A Systematic Review. *Child (Basel, Switzerland)* 2021;**8**. doi:10.3390/children8121134

30 Bond M, Bergdahl N, Mendizabal-Espinosa R, *et al.* Global emergency remote education in

secondary schools during the COVID-19 pandemic: A systematic review. 2021.

31 Zhang Y, Bao X, Yan J, *et al.* Anxiety and Depression in Chinese Students During the COVID-19 Pandemic: A Meta-Analysis. Front. public Heal. 2021;**9**:697642. doi:10.3389/fpubh.2021.697642

32 Elharake JA, Akbar F, Malik AA, *et al.* Mental Health Impact of COVID-19 among Children and College Students: A Systematic Review. *Child Psychiatry Hum Dev* 2022;:1–13. doi:10.1007/s10578-021-01297-1

33 Meherali S, Punjani N, Louie-Poon S, *et al.* Mental Health of Children and Adolescents Amidst COVID-19 and Past Pandemics: A Rapid Systematic Review. *Int J Environ Res Public Health* 2021;**18**. doi:10.3390/ijerph18073432

34 Samji H, Wu J, Ladak A, *et al.* Review: Mental health impacts of the COVID-19 pandemic on children and youth - a systematic review. *Child Adolesc Ment Health* Published Online First: August 2021. doi:10.1111/camh.12501

35 Viner R, Russell S, Saulle R, *et al.* School Closures During Social Lockdown and Mental Health, Health Behaviors, and Well-being Among Children and Adolescents During the First COVID-19 Wave: A Systematic Review. *JAMA Pediatr* Published Online First: January 2022. doi:10.1001/jamapediatrics.2021.5840

36 Lehmann J, Lechner V, Scheithauer H. School Closures During the COVID-19 Pandemic: Psychosocial Outcomes in Children-a Systematic Review. *Int J Dev Sci* 2022;:1–27.

37 Chai J, Xu H, An N, *et al.* The Prevalence of Mental Problems for Chinese Children and Adolescents During COVID-19 in China: A Systematic Review and Meta-Analysis. Front. Pediatr. 2021;**9**:661796. doi:10.3389/fped.2021.661796

38 Cui Y, Li F, Leckman JF, *et al.* The prevalence of behavioral and emotional problems among Chinese school children and adolescents aged 6-16: a national survey. *Eur Child Adolesc Psychiatry* 2021;**30**:233–41. doi:10.1007/s00787-020-01507-6

39 Chang T-H, Chen Y-C, Chen W-Y, *et al.* Weight Gain Associated with COVID-19 Lockdown in Children and Adolescents: A Systematic Review and Meta-Analysis. *Nutrients* 2021;**13**. doi:10.3390/nu13103668

40 Sharma M, Aggarwal S, Madaan P, *et al.* Impact of COVID-19 pandemic on sleep in children and adolescents: a systematic review and meta-analysis. *Sleep Med* 2021;**84**:259–67. doi:10.1016/j.sleep.2021.06.002

41 Kourti A, Stavridou A, Panagouli E, *et al.* Domestic Violence During the COVID-19 Pandemic: A Systematic Review. *Trauma Violence Abuse* 2021;:15248380211038690. doi:10.1177/15248380211038690

42 Krishnaratne S, Littlecott H, Sell K, *et al.* Measures implemented in the school setting to contain the COVID-19 pandemic: a rapid review. *Cochrane Database Syst Rev* 2022;**2022**. doi:10.1002/14651858.CD015029

43 Vardavas C, Nikitara K, Mathioudakis A, *et al.* The role of educational settings in the transmission chain of SARS-CoV-2 in 2020: a systematic review. *medRxiv* Published Online First: 2021. doi:10.1101/2021.10.13.21264932

44 Fukumoto K, McClean CT, Nakagawa K. No causal effect of school closures in Japan on the spread of COVID-19 in spring 2020. *Nat Med* 2021;**27**:2111–9. doi:10.1038/s41591-021-01571-8

45 Arnaout R, Arnaout R. Visualizing omicron: COVID-19 deaths vs. cases over time. *PLoS One* 2022;**17**:e0265233. doi:10.1371/journal.pone.0265233

46 Andrews N, Stowe J, Kirsebom F, *et al.* Covid-19 Vaccine Effectiveness against the Omicron (B.1.1.529) Variant. *N Engl J Med* 2022;**386**:1532–46. doi:10.1056/NEJMoa2119451

47 Cuadros DF, Moreno CM, Musuka G, *et al.* Association Between Vaccination Coverage Disparity and the Dynamics of the COVID-19 Delta and Omicron Waves in the US. *Front Med* 2022;**9**:898101. doi:10.3389/fmed.2022.898101

48 Chalkias S, Harper C, Vrbicky K, *et al.* A Bivalent Omicron-Containing Booster Vaccine against Covid-19. *N Engl J Med* 2022;**387**:1279–91. doi:10.1056/NEJMoa2208343

49 Risk M, Miao H, Freed G, *et al.* Vaccine Effectiveness, School Reopening, and Risk of Omicron Infection Among Adolescents Aged 12-17 Years. *J Adolesc Heal Off Publ Soc Adolesc Med* Published Online First: October 2022. doi:10.1016/j.jadohealth.2022.09.006

50 Tan SHX, Cook AR, Heng D, *et al.* Effectiveness of BNT162b2 Vaccine against Omicron in Children 5 to 11 Years of Age. *N Engl J Med* 2022;**387**:525–32. doi:10.1056/NEJMoa2203209

51 Cowger TL, Murray EJ, Clarke J, *et al.* Lifting Universal Masking in Schools - Covid-19 Incidence among Students and Staff. *N Engl J Med* Published Online First: November 2022. doi:10.1056/NEJMoa2211029

52 Hume S, Brown SR, Mahtani KR. School closures during COVID-19: an overview of systematic reviews (Supplementary Table 3). Published Online First: 2023. doi:https://doi.org/10.6084/m9.figshare.21803883.v1